# ON THE DEVELOPMENT AND A SUPPQSED NEW METHOD OF REPRODUCTION IN THE SUN-ANIMALCULE—ACTINOSPHARIUM EICHHORNII.

JOHN M. STEDMAN, B.S., Ithaca, N. Y.

Early in March my attention was called to an aquarium which had been standing in my window during the winter, and which contained anacharas and algae in great abundance, but which now suddenly presented a quantity of light pink substance on the sides of the jar. It was the appearance of this pink-colored material among the debris of decaying and growing algae that attracted my attention. Accordingly a small piece of the substance was spread out on a slide and examined, when, to my surprise, it was found to be composed of sun-animalculae of various sizes, among which were other bodies, the true nature of which I did not at first quite understand, but which on close examination proved to be the young of the larger heliazoa. So numerous, indeed, were the young heliazoa that not a single field of the one-fifth objective and *a* ocular could be chosen in which there were less than half a dozen, and usually the number was very much greater.

Such an unusually great and rare opportunity to study these animals could not be neglected. Fortunately they were discovered in the morning, and by close and constant observation for several hours their true relations to the numerous small bodies were satisfactorily demonstrated and proven to be different stages of the same animal.

For a description of *A. Eichornii* and of its habits see "Fresh-water Rhizopods of North America," by J. Leidy, p. 259. Plate XLI.

We will pass at once to the special subject in hand, beginning, for convenience, with the simplest or youngest heliazoan.

*Development.* — Let it not be understood that the order in which I am now to describe the different stages of development is the order in which I observed them. On the contrary, what I shall first describe really came about last in my observations, since I did not at first take the youngest stages of this heliazoan to have any connection with the larger heliazoa. My observations began with an undoubted heliazoan of this species (Fig. 13, of my plate), and from that I worked both ways, but principally to the younger. It would have been impracticable to have watched the development of a single heliazoan from the very youngest individual to the full-grown animal, since it would have required not only a constant observation for a much longer time than I could spare, but would also have needed some little care. As it was, I could watch a young heliazoan until it had developed a few stages, and had considerably lessened the near supply of food, and then I could find another heliazoan of the same stage as the one just discarded, but which was in more favorable circumstances for further growth. As indicated, the number of heliazoa was enormous, and the different stages were represented by the score. Had I suspected these various stages to have been what they were, there would have been no trouble in finding a complete set, for every gradation from the youngest to the adult was present in great quantities. Fortunately there were quite a number of worms — *Dorylaimus stagnalis* — in the water, and their constant wriggling about kept the heliazoa and other animals in perpetual motion, so that they came in contact with one another, where otherwise they would not have done so.

A far greater number of observations were made than I shall here describe. Enough were chosen, however, to form a complete series, and accurate drawings made of them. I shall, therefore, describe only those observations which I have illustrated, hoping that the series will be full enough for our purpose.

I think it is safe to say that were this minute mass of protoplasm which constitutes the youngest heliazoan observed by itself for a little while, no one would mistrust its true nature or relations. Indeed, it was only after a long and continued observation, and that under the most favorable circumstances, that I became convinced of its true nature. It is nothing but a minute spherical mass of finely granular and hyaline protoplasm, 14.5 $\mu$ in diameter, with a contained nucleus and a distinct nucleolus (Fig. 1). In appearance it resembles white blood corpuscles with a distinct and sharply defined nucleus. Later, however, a vacuole appears in its substance, and, increasing in size, often becomes larger than the original mass of protoplasm, so that the latter forms but a thin layer surrounding it (Figs. 2, 16, 12). In this stage a pseudopodeum or ray may be presented (Fig. 12).

Two heliazoa of the first stage were seen to come together, which, however, as in nearly all cases, was due to the agitation of the water by the worms, and immediately upon touching one another (Fig. 23), to fuse and run together just as a drop of water fuses with another drop of water. It is impossible to say which of the two was devoured ; both appeared to play an equal part, the vacuole and nucleus of both being present, and the whole immediately assuming a spherical form and appearing (Fig. 3) much like any one of the two of which it is now composed, except that it has two vacuoles and two nuclei. In the course of five minutes this young, two-vacuoled, heliazoan had developed a ray, and in its interior the characteristic axis thread could be distinctly seen (Fig. 20). The absence or the number of rays when present in the

young heliazoa is of no special value, and varies with different individuals of the same age, as will be seen from the figures.

Whether this fusion of two individuals of the same species be called eating or not does not concern us, and I shall not attempt to discuss the subject here. As a matter of fact however it is not conjugation for purposes of reproduction or rejuvenescence, as will be seen later; and, since we have these animals developing by this method of increase as well as by that of an undoubted eating of other animals, it matters not, so far as development is concerned, whether they appropriate material so near like that of their own bodies that it needs no change to form a part of them, or whether the food be different and hence have to be changed or digested before it can be so appropriated. I have observed farther advanced heliazoa capture infusoria and amoeba and surround them, and draw them into their interior, where they remained to be digested; and at the same time I have observed those same heliazoa capture other heliazoa, and instead of drawing them into their interior and surrounding them as they did other bodies, they would draw them in until the two heliazoa touched, when there occurred a fusing and blending of the two animals into one just so much larger. My only explanation is that, as indicated, the protoplasm of the two animals is *exactly alike* and hence there can be no need of digestion. Were one of the heliazoa dead when it came in contact with another which would otherwise have fused with it, I have no doubt but that the dead heliazoan would be surrounded and drawn into the interior of the live one the same as other animals are and there digested, it being *not exactly like* the protoplasm of the one which is alive. For if this were not the case, if the dead heliazoan upon contact with the living heliazoan were to form a part of it as the living heliazoan did, then we should have a case where simple contact of the living protoplasm with the same but dead protoplasm would impart life

to the dead, just as a piece of iron which is magnetized, if brought in contact with one which is not, will impart magnetism to it. But it is needless to say that such a phenomenon of life has never been observed.

While watching the heliazoan (Fig. 3, 20) which we have just described as being the result of the union of two of the youngest individuals (Fig. 2, 23), the water was stirred by a worm, and another heliazoan, of about the same size as the one under observation but with three vacuoles and no rays, was brought nearer and nearer until finally they accidentally came in contact with one another and immediately united (Fig. 20) and assumed a spherical form. Presently the single ray disappeared and three more vacuoles made their appearance in the mass of protoplasm together with the development of a contractile vesicle (Fig. 5). This individual was watched until it had developed three rays and several more vacuoles (Fig. 6), a process requiring about twenty-five minutes, during which time it had eaten nothing except one of the youngest heliazoa without a vacuole. Under the one-twelfth oil emersion I was able to detect the axis cylinder in two of the rays, but not without some doubt in the third ray.

Very near this individual (Fig. 6, 26) was another heliazoan of a much greater size (Fig. 25), and by touching the cover-glass with a needle I soon brought the two so near that the tip of one of the rays of the smaller heliazoan touched the larger animal. Wishing to observe the result of this contact I waited a few minutes, when it became apparent that the smaller individual was drawing in its ray, which was in contact with the larger heliazoan, and was thus drawing itself towards it. The larger animal, offering the greater resistance, did not appear to move. Five minutes from the time the ray first touched the other heliazoan the two had come in contact, whereupon a union occurred and immediately the two blended into one. The smaller animal appeared to flow into the larger and to disperse itself through it in a

manner which is common to all these animals, young as well as full-grown, and which will be described later when we reach a nearly mature heliazoan. Before the union of these two animals they appeared alike except in size and number of vacuoles, but shortly after the union the granules in the protoplasm gradually moved towards the center of the animal, where they became more numerous, and instead of being evenly distributed throughout the granular protoplasm now formed a central, more granular portion with an outer, clearer, and less granular zone. Three more rays were also developed, and the animal presented the appearance shown in figure 7, which, at this stage, would probably not be mistaken for any other species. Hundreds of individuals were to be found of this size and appearance, and hence it was not necessary to watch the development of this single individual longer, as other fields promised better results.

There was almost an unlimited supply of heliazoa intermediate in size between the two whose union produced the one just mentioned. They differed in no respect from one another or from the two just mentioned, except a slight difference in size, and every gradation between them was to be found. Merely for the sake of filling up the gap which exists in regard to size between the two individuals whose union we just referred to, I will cite one example out of many which I have observed. Two similar individuals, slightly larger than the smaller (Fig. 26) of the two just united were seen to come together (Fig. 22), and, as a result of their union, a heliazoan was produced so nearly like the larger (Fig. 25) of the two of the former individuals, that there was practically no difference between them.

Another field was now chosen in which were a number of heliazoa, similar in all respects to the one representing our last stage (Fig. 7). I had not waited long before it was evident that two of these animals were gradually approaching one another from some cause which I was unable to discover.

When within a very short distance, in fact almost ready to meet, there occurred a very singular movement on the part of both individuals — a movement which I can hardly account for — in which there was produced a swelling, as it were, in that part of the sphere of both animals (Fig. 8, 9) which was just about to touch the other, and by continued enlarging with increased rapidity soon met one another, thus uniting the two individuals much more quickly than they otherwise would have done. Immediately upon touching one another the at first narrow neck uniting them rapidly enlarged (Fig. 10), the protoplasm of the one flowing into the other and *vice versa* until the two animals had united into an oblong-shaped mass. The flowing of the protoplasm from one to the other was a most interesting sight, and could be distinctly seen, owing to the numerous granules which it contained. Both animals played an equal part in the union; a current of protoplasm could be seen streaming from the first into the second, and near it another current from the second into the first. There were as many currents as there were threads of denser protoplasm uniting them. Like all the observed cases, the denser and more granular portions of the protoplasm separating the vacuoles from one another never mixed with anything but the corresponding protoplasm of the individual with which it united; hence there was no destruction of vacuoles, but merely an addition or union, and, moreover, the peripheral layer of vacuoles always remained on the periphery, while the central mass of vacuoles flowed to the center of the united mass. The heliazoan now gradually changed from the oblong or ellipsoid shape to that of a sphere (Fig. 11), and here I left it to seek other fields.

A nearly identical individual to the one just mentioned was found and seen to capture by one of its rays another but smaller heliazoan. As a result of a movement of the water, the smaller individual chanced to come in contact with the tip of a ray of the larger animal and there to unite with it,

whereupon the larger heliazoan gradually drew in its ray and the smaller creature with it. It was an interesting sight to see this process. The ray seemed rather to flow into the spherical mass or body of the animal, since a stream of protoplasm was rapidly and constantly flowing down its center into the animal, and the smaller heliazoan was likewise flowing into the larger by this means; but, nevertheless, the ray grew shorter and shorter until finally the heliazoa came in contact (Fig. 13), and then a union took place similar to the one described above, except that here the flow of protoplasm appeared to be solely from the smaller to the larger animal. Before the animal had become entirely spherical, the denser inner portions of the smaller heliazoan had united with that of the larger and appeared as a swelling upon it, while the peripheral zones of both animals had united. This appeared to be such a good example of the mode of union of the protoplasm of two heliazoa that I figure it (Fig. 15).

I have observed a number of large heliazoa capture the youngest individuals, and in all cases as soon as the young animal touched the ray of the larger it appeared, so to speak, to form a part of it, and would sometimes assume an oval form and remain on the ray, looking exactly like the little knobs of protoplasm which are frequently seen there, except that it would be larger; and then again I have seen them flow down the center of the ray, while the ray itself suffered no appreciable change. In one instance, however, which came under my observation, a moderately sized heliazoan (Fig. 17) captured by the tip of its ray one of the youngest individuals (Fig. 16), and while watching to see what would happen to this young one, the ray of a large heliazoan (Fig. 18) came in contact with the larger of the former animals. Out of curiosity merely I watched to see the result of this extraordinary union, and found that the largest heliazoan drew its captured brother to itself and united with it before the smallest individual had touched the body of the one to

which it was attached; the smallest heliazoan then appeared to be fastened to a ray of the largest animal, which, however, soon drew it to itself and the two united.

Quite a different process from the one we have been discussing occurs when the heliazoan encounters food consisting of other animals or plants. I have no doubt but that the youngest heliazoan, as well as those of all stages, are able to and generally do develop and reach maturity by the use of no food other than that of other animals and plants; but there is also no doubt that this is a process requiring considerable time as compared with that which occurs when they chance to meet with their own kind, since in the former case the food has to be digested, while in the latter it has not. It was my good fortune to find a large heliazoan which had just captured an infusorium and partially surrounded it. In a few minutes the infusorium was completely enclosed, a clear space remaining around it, however, and gradually it was moved near the center of the animal, where it could be seen slowly moving its cilia in the little water which immediately surrounded it and which separated it from the protoplasm of the heliazoan (Fig. 19, 21). Presently an amoeba came in contact with the heliazoan and appeared to stick to it more or less and to constantly try to move away from it. The heliazoan made several efforts to surround it, but the amoeba in every case moved out before fairly imbedded, and finally, after several minutes of hard struggling to ascertain which was to be victorious the amoeba escaped. It was but a short time, however, before another amoeba chanced to touch the heliazoan, and this time with better success to the heliazoan. The amoeba, as soon as it touched the heliazoan, spread out a little on it, and at the same time the protoplasm of the heliazoan began to flow around and to enclose the amoeba, which now made several efforts to escape, but in vain, for within a few minutes a fine film of protoplasm had surrounded it, and the amoeba was within the heliazon (Fig. 19). A quantity

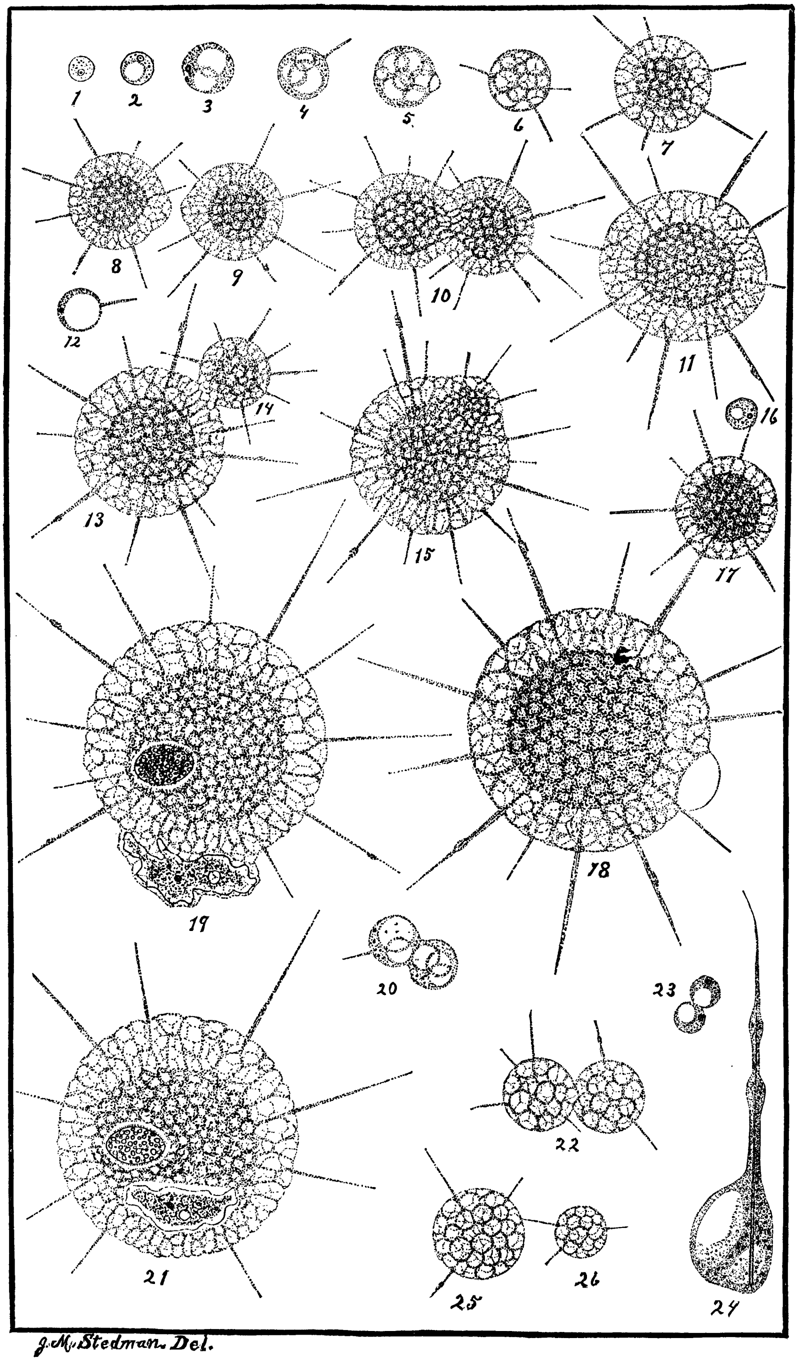
of water was also enclosed with the amoeba, and in this it exhibited considerable activity, even after it had been carried nearly to the center of the heliazoan (Fig. 21). It was not long, however, before the amoeba had assumed a globular form and become motionless. I mention this instance in which the heliazoan eat other animals, merely to bring out the striking difference between the process and that observed when they eat their own species.

Dr. Joseph Leidy * speaks of having found several globules of granular protoplasm with vacuoles and rays, and alludes to their probable connection with this species of heliazoa. I have reproduced in figure 24 one of his figures of these bodies, and think that there is every reason to believe that they are what he suspected them to be.

*Reproduction.* — It is not uncommon to find heliazoa in the process of reproduction by fission, in fact if heliazoa be kept for any considerable length of time they are almost certain to be found in the act of reproducing by this means. I have observed them divide by keeping them in a watch-glass under the microscope, and in one instance I watched uninterruptedly the process, from an oral heliazoan before the constriction began to appear, up to the division and entire separation into two animals. A complete set of drawings was made to illustrate the different steps, and I find by referring to my notes that one of the drawings is almost identical with figure 10, which represents the heliazoan in the process of union.

As regards reproduction in the heliazoa outside of the well-known process of fission, all I can say is from a philosophical standpoint, as no direct observations have been made outside that of the finding of the young. But the presence of young has got to be explained in some way. From Dr. Leidy's "Fresh-water Rhizopods," p. 260, I find that "according to Stein, Carter, and other authorities, *A. Eichhornii* contains many nuclei, large individuals having a hun-

* "Fresh-water Rhizopods of North America," page 262–3.




J. M. Stedman, Del.

dred or more." Whether this has any connection with the heliazoan's having devoured individuals of its own species and thus to have retained their nuclei, and so, by continually adding to the number every time it captured another heliazoan, to have finally attained the number of one hundred, or whether it is connected with the process of reproduction, I cannot say. It seems to me very probable that, in the fall at least, the full-grown heliazoan becomes encysted, and that its protoplasm then divides and subdivides, until it is converted into a mass of minute bodies, which, when the cyst is ruptured, make their escape into the surrounding water, and then appear as naked, spherical masses of granular protoplasm with a nucleus. It may be that the minute bodies acquire a covering before they escape from the mother cyst, and that they then act as spores, and are carried about and developed similar to the spores of infusoria.

Of course this mode of development has never been observed in the heliazoan, but it seems to me to be very probable that it does occur, judging from the observed young individuals, and from the fact that it occurs in certain infusoria.

## EXPLANATION OF PLATE.

All the figures were drawn from life except Fig. 24, which is a reproduction of a figure from Dr. Leidy's work on the Rhizopods. Fig. 1, which is a heliazoan, *Actinosphaerium Eichhornii*, of the very youngest stage, is in nature $14.5\mu$ in diameter. The other figures are drawn with the same magnification as Fig. 1, and hence they all bear the same relative size in nature as is here represented, excepting Figs. 25 and 26, which are a little too small. I take it to be of much more value to the reader to have the figures drawn so as to preserve their relative size, and then to know the natural size of one of them, than it is to have the figures of various magnifications and know the magnification of each separate figure. I do not wish it understood that the figure taken from Leidy is relatively of the same size as the other figures.